J. HYM. RES.
Vol. 17(1), 2008, pp. 116–123

A Comparison of the Parasitic Wasps (Hymenoptera) at Elevated Versus Ground Yellow Pan Traps in a Beech-Maple Forest

Thomas Pucci

Department of Invertebrate Zoology, Cleveland Museum of Natural History, 1 Wade Oval Dr. Cleveland, Ohio, 44106, USA; email: tpucci@cmnh.org

Abstract.—The abundance, diversity, and morphospecies composition of the parasitic wasp fauna is compared at two levels in an Ohio (USA) temperate forest. The ground layer and the elevated layer (~10m) exhibited similar abundance but a distinctly different composition. The diversity at the ground layer was greater. Encyrtidae were captured more often in elevated traps while Pteromalidae, Ichneumonidae, and alysiine Braconidae were more prevalent at ground level. A retrospective analysis of the edge effect showed no difference in the composition relative to distance from forest edge but elevated samples had a higher diversity near the edge than in the interior.

A key goal in ecology is to describe the distribution of species within the environment. However, difficulty of canopy access has limited our knowledge of forest communities (Ozanne et al. 2003). A better understanding of arthropod forest stratification is needed to identify which taxa are dependent on elevated strata and under what conditions do distinct stratum communities develop. This will direct more efficient and thorough surveys of forest life.

There are many accounts of arthropod stratification in tropical forests. Many document increased abundance (e.g. Kato et al. 1995, Barrios 2003, Sutton and Hudson 1980) and diversity (e.g. Basset 2001a, Basset et al. 2001, Rees 1983, Yanouvial and Kaspari 2000) in elevated layers. Contradictory results however are evident. For example, Stork and Grimbacher (2006) found a similar abundance and richness of beetles between ground and elevated layers. Abundant arthropod stratum specialists have also been observed (Schulze et al. 2001, Hammond et al. 1997, Sorensen 2003).

Temperate forests are also stratified but patterns are similarly not well established. The stratum of peak abundance has been shown to be variable: elevated (Hollier and Belshaw 1993); near ground (Nielsen 1987), or comparable (Le Corff and Marquis 1999, Preisser et al. 1998, Ulyshen and Hanula 2007). In several studies diversity has been shown to be greater near ground level (Lowman et al. 1993, Le Corff and Marquis 1999, Ulyshen and Hanula 2007). Distinct stratum communities were revealed in the preceding and by Winchester and Ring (1996), Gibson (1947) and Hollier and Belshaw (1993). But Fowler (1985) observed little stratification in richness or species composition of herbivores on birch branches. Examples of stratification involving a limited number of species include Munster-Swendsen (1980) and Henry and Adkins (1975).

Although there has been pronounced growth in canopy research in recent decades (Basset 2001b), basic questions regarding forest stratification remain. I am not aware of another temperate zone species-level survey that addresses the complete parasitic wasp fauna at ground versus elevated strata. The purpose of this study is to compare the composition of adult parasitic wasps at two levels of a temperate forest.

METHODS

The study site is located within the Soubusta Sugarbush Preserve (041°34′24″ N 081°14′04″ W) in northeastern Ohio, USA. Canopy trees are dominated by sugar maple (*Acer saccharum* Marshall) and American beech (*Fagus grandifolia* Ehrh.). Tulip tree (*Liriodendron tulipifera* L.) is also common. Ground cover is dominated by sugar maple seedlings, mayapple (*Podophyllum peltatum* L.), white trillium (*Trillium grandiflorum* Salisb.), and white ash (*Fraxinus americana* L.) seedlings. The site was deforested in the 19th century and has been harvested for maple syrup since the 1940s but apparently no tree thinning has been practiced (K. Vouk, pers. comm.). The study site is within a forested lot which is approximately 85 hectares and connected to other lots by a corridor.

Traps were made from plastic containers spray-painted fluorescent yellow. The dimensions (L-W-D) were 20×15×10 cm. A bow and arrow were used to string a line for eight traps hung over sugar maple limbs. Trap placement was dictated by the presence of an accessible tree limb under the closed canopy. Elevated trap placement ranged from 6.7 to 11.9 meters (mean 9.8 m) high. A ground level trap was placed directly under each elevated trap. Rope was attached to the trap and fastened to a nearby tree to mimic the elevated trap set-up. All traps were filled half way with water and a few drops of unscented detergent.

Traps were serviced every two days from June 3rd to July 1st 2005. Specimens of parasitic wasps (including all Cynipoidea; excluding Dryinidae) were pointed and sorted to morphospecies. Occasionally, within a single pan sample, only representative specimens of a common morphospecies were pointed. Inherent in the concept of morphospecies is the likelihood of misclassification. Approximately 60 hours were spent sorting specimens in an effort to minimize this occurrence. Seventeen specimens are unassigned to morphospecies owing to damage or uncertainties regarding sexual dimorphism. Specimens were taken at least to family level using Goulet and Huber (1993). Braconid specimens were taken to subfamily using Wharton et al. (1997). Representative specimens are housed at the Cleveland Museum of Natural History.

Paired *t* tests were used to compare various components of each stratum. The Mann-Whitney Rank Sum Test was used when the data were not normally distributed. The Simpson Index of diversity was used as recommended by Magurran (2004). The Morisita-Horn index was used to measure the faunal similarity between groups. It uses abundance data and is preferable because it is not dependent on sample size (Krebs 1999).

All traps were within 250 meters of each other. Two pairs of traps (sites #1 and #2) were placed approximately 25 m from an old field while the remaining were situated 100 ± 10 meters from the forest edge. Although this set-up was not designed to address any edge effects, a retrospective comparison of these two groups was carried out. To examine the faunal composition of the sites, a cluster analysis using MVSP version 3.130 (Kovach 2005), the UPGMA clustering method, and the modified Morisita's coefficient of similarity was executed. Also, the Morisita-Horn index was compiled for each pair of traps per stratum. Trap pairs sited a similar distance from the edge were compared with those sites at differing distances by means of a *t* test.

RESULTS

A total of 2,541 specimens and 269 morphospecies were collected. The braconid, *Eubazus pallipes* Nees, represents 36.4 % of the total catch. Ninety-five percent of the specimens (878 specimens) were from a single elevated trap taken during five consecutive collecting dates. Therefore, *E. pallipes* is not included in the following

Table 1. Abundance and diversity of each stratum.

	Abundance	Number of species	Simpson index (1/D)
Elevated *	703	147	20.18
Ground *	837	183	41.79
Mean (SD) **	elev. 6.38 (2.84) gr. 7.61 (3.21)	elev. 4.92 (1.34) gr. 6.35 (2.47)	elev. 0.915 (0.041) gr. 0.941 (0.025)
t test (N = 30) **	t = −1.114 P = 0.275	t = −1.964 P = 0.059	t = −2.164 P = 0.039

* data deleted to yield equal collection effort (216 trap days per stratum)
** based on raw data

analysis where it would skew the results. Traps were occasionally disturbed, resulting in unequal collection effort between the strata. This was corrected for by deleting the data from each pair of traps when one was disturbed in comparisons that do not use the mean.

The abundance of parasitic wasps was similar between strata (Table 1). The diversity was significantly higher at ground level based on the Simpson Index but marginally insignificant based on species richness (Table 1). Based on equal collection effort, there were 130 singletons: 54 from elevated traps and 76 at ground level. This does not represent a significant difference (t = −1.25, P = 0.223).

The inter-strata similarity is low, 0.353, compared to the mean (SD) of the within stratum similarity: elevated 0.708 (0.088), ground 0.586 (0.084). Similarly, Figure 1 shows the composition of the strata were distinct. Table 2 lists the taxa with at least ten specimens. Six of the 14 families and 21 of the 45 morphospecies were significantly more abundant in a particular stratum. Excluding *Eubazus pallipes* (from the trap with the exceptional catch), the abundance of the 21 "stratum specialists" represented 67% of the "common morphospecies" listed in Table 2. This proportion rises to 71% if the morphospecies at P ≤ 0.08 are considered stratum specialists.

The influence of the edge effect on diversity is shown in Table 3. There was a significantly higher diversity in the elevated traps near the edge but no significant difference at ground level. Table 4 and Figure 1 show no edge effect in the species composition for either stratum.

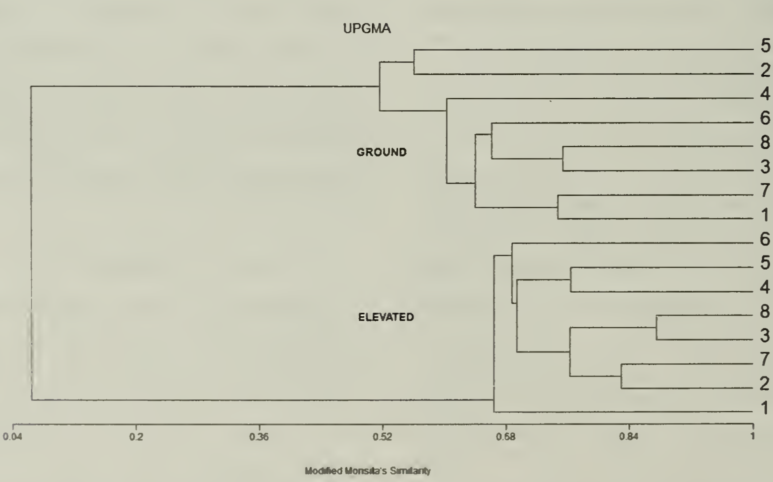

Fig. 1. Cluster analysis of the abundance based species composition for each trap. Sites one and two were approximately 25 meters from the forest edge while the remaining were approximately 100 meters away.

DISCUSSION

The parasitic wasp fauna differed between strata at the family level (individuals per family) and the morphospecies level. Although elevated traps were in the lower reaches of the sugar maple canopy and the forest floor contained abundant sugar maple seedlings, numerous taxa were found in significantly higher numbers in the elevated traps. Likewise, some morphospecies exhibited a preference for the ground level. My results are consistent with Le Corff and Marquis (1999) and Ulyshen and Hanula (2007) who also found distinctly different insect communities at elevated and near ground strata in temperate habitats. Additionally, they also found the near ground stratum was more diverse.

These results are consistent with Lowman et al. (1993) who hypothesized that the stratum of peak diversity will generally be near the ground in temperate forests and in the canopy in tropical forests, coinciding with the stratum with the most niches. Further evidence includes Leksono et al. (2005) who used both yellow and blue pan traps to survey attelabid and cantharid (Coleoptera) stratification in a mixed deciduous forest in Japan. Although common species were more abundant at the highest (20m) layer, rare species were found only at the lower layers (0.5m and 10m). In contrast, the canopy is often shown to be more diverse in tropical forests (e.g. Basset 2001a, Rees 1983, Yanouvial and Kaspari 2000).

The particular sampling regime in this study precludes examination of the influence of some known factors that affect insect collections. Seasonality has been shown to influence guild structure (Askew and Shaw 1979, Sheehan 1994). Ulyshen and Hanula (2007) found the ground: canopy ratio of abundance and richness is liable to change significantly throughout the collecting season. Ozanne (1999) found guild structure changes with tree species. Davis and Sutton (1998) found forest type influences the vertical distribution of certain dung beetles. Also, it is well known that collecting method influences the composition of parasitic wasp samples (Noyes 1989, Idris et al. 2001). Perhaps because yellow pan traps are attractive the focus on a single tree species is not necessary to collect comparable samples in the canopy but this has not been established.

The edge effect has been shown to change the species composition and increase the abundance of insects (e.g. Noyes 1989, Foggo et al. 2001). The lack of a decipherable edge community in this study could be due to the rather distant (25 m) location of the "edge" sites. Alternatively, the gradient may be much weaker. For example, Dangerfield et al. (2003) found habitat specialists can be prevalent for hundreds of meters beyond a discrete riparian/treeless saltbush edge. In this study, elevated edge sites displayed a greater diversity than the elevated interior sites but there was no significant difference at ground level. These results are preliminary due to the lack of replication of edge sites, but suggest that further work into the edge/canopy effect on parasitic wasps may be fruitful for building our knowledge of wasp biology and forest ecology.

The stratification displayed in Fig. 1 and Table 2 probably largely reflects host distribution. For example, alysiine braconids and the majority of diapriids attack immature Diptera which predominate in the soil layers of temperate forests (Schaefer 1991). Additionally, others have found certain groups of egg parasitoid abundance to be greater in elevated layers (Compton et al. 2000, Basset et al. 2001, Noyes 1989). Mymaridae however has been shown to be low fliers (Compton et al. 2000, Noyes 1989). Compton et al. (2000) demonstrated various chalcid families (esp. fig wasps) can be found above the canopy where there is stronger wind. A strong case is made that their presence at that height is associated with dispersal. Perhaps some parasitic

Table 2. List of taxa with at least ten specimens and a comparison of the vertical distribution.

Taxa	Elevated Abundance 238 trap days	Ground Abundance 218 trap days	*t* test (t) or Mann-Whitney Rank Sum test (T)
Ceraphronoidea			
Ceraphronidae	51	41	t = −0.305 P = 0.763
#1	6	12	T = 269 P = 0.134
#2	11	12	T = 249 P = 0.520
#3	**25**	3	**T = 173 P = 0.015**
Chalcidoidea			
Encyrtidae	**146**	27	**t = −5.30 P = < 0.001**
#1	9	2	T = 208 P = 0.316
#2	22	7	T = 199 P = 0.170
#3	10	8	T = 238 P = 0.835
#4	**33**	0	**T = 158 P = 0.002**
#5	**28**	0	**T = 150 P = < 0.001**
#6	**22**	1	**T = 177 P = 0.021**
Eulophidae	39	19	t = −1.75 P = 0.092
#1	11	0	T = 173 P = 0.130
#2	1	**9**	**T = 280 P = 0.05**
#3	10	1	T = 202 P = 0.202
Mymaridae	138	79	T = 209 P = 0.330
Stephanodes sp.	7	**23**	**T = 287 P = 0.025**
#1	**121**	31	**t = −2.98 P = 0.006**
#2	9	6	T = 220 P = 0.602
Pteromalidae	15	**36**	**t = 2.35 P = 0.026**
#1	1	**18**	**T = 281 P = 0.047**
Cynipoidea			
Charipidae	12	2	T = 208 P = 0.316
#1	11	2	T = 208 P = 0.316
Cynipidae	14	31	T = 275 P = 0.081
#1	8	22	T = 259 P = 0.288
Eucoilidae	1	**9**	**T = 288 P = 0.022**
Evanioidea			
Aulacidae	10	0	T = 188 P = 0.063
Ichneumonoidea			
Braconidae	984	113	T = 232 P = 0.983
Alysiinae	7	**68**	**T = 326 P = < 0.001**
Aphaereta pallipes (Say)	1	9	T = 272 P = 0.103
Dinotrema sp.	3	17	T = 276 P = 0.073
Aphidiinae	20	7	T = 214 P = 0.441
Trioxys sp.	19	6	T = 214 P = 0.453
Doryctinae	14	31	T = 277 P = 0.071
Spathius elegans Matt.	4	**29**	**T = 303 P = 0.004**
Euphorinae	8	2	T = 202 P = 0.203
Helconinae	**927**	1	**T = 154 P = 0.001**
Eubazus pallipes Nees	**924**	1	**T = 169 P = 0.009**
Ichneumonidae	45	**131**	**T = 321 P = < 0.001**
#1	1	9	T = 257 P = 0.315
#2	2	13	T = 255 P = 0.357
#3	0	**13**	**T = 293 P = 0.013**
#4	3	15	T = 272 P = 0.109
#5	2	12	T = 275 P = 0.080
Platygastroidea			
Platygastridae	158	97	T = 216 P = 0.507
#1	**104**	24	**T = 172 P = 0.012**
#2	8	6	T = 240 P = 0.787
#3	4	7	T = 241 P = 0.738

Table 2. Continued.

Taxa	Elevated Abundance 238 trap days	Ground Abundance 218 trap days	*t* test (t) or Mann-Whitney Rank Sum test (T)
#4	7	13	T = 263 P = 0.219
#5	12	13	T = 233 P = 1.0
#6	2	10	T = 275 P = 0.080
#7	3	**17**	**T = 299 P = 0.006**
Scelionidae	**40**	8	**T = 164 P = 0.004**
Telenomus sp.	**20**	3	**T = 171 P = 0.010**
Trissolcus sp.	11	0	T = 195 P = 0.121
Proctotrupoidea			
Diapriidae	22	**244**	**T = 341 P = < 0.001**
Basalys sp.	5	**22**	**T = 293 P = 0.013**
Paramesius sp.	0	**17**	**T = 285 P = 0.030**
Spilomicrus sp.	1	10	T = 249 P = 0.502
Trichopria sp.	2	**38**	**T = 326 P = < 0.001**
#1	2	**87**	**T = 335 P = < 0.001**
#2	5	**15**	**T = 283 P = 0.039**
#3	0	**11**	**T = 285 P = 0.030**
#4	0	**14**	**T = 300 P = 0.005**

wasps in temperate forests use elevated layers for dispersal. Evidence for this include Karem et al. (2006) who found the abundance of small wasps (many Chalcidoidea, Cynipoidea, and Proctotrupoidea) was similarly stratified along forest/field transects so that the wasps were flying in the canopy in addition to well above field vegetation. Nielsen (1987) found the greatest wind speeds just below the canopy (10m) in a fully leaved beech stand. Using light traps, it was shown that insects in general (including Hymenoptera) avoided this layer compared to traps at 0.6 m and 21 m. Unfortunately, the Hymenoptera composition per level was not documented.

Similar to my results, other studies that have compared canopy versus near ground level insects have found approximately half of the common species to be associated with a particular stratum, about a quarter at each level (Stork and Grimbacher 2006, Broadhead 1983). Likewise, Ulyshen and Hanula (2007) report that the proportion of beetle species captured exclusively at a particular stratum to be approximately 30 % at each layer. Although most of the taxa with at least ten specimens are found at both strata in my study, it has been shown that the fauna collected at only one layer gives a biased representation of the composition of parasitic wasps.

Table 3. Edge effect and diversity for each stratum.

	Simpson Index		
Distance from edge	N	Mean (SD)	*t* test
Elevated			
~25 m	2	17.24 (2.50)	t = 2.91
~100 m	6	10.81 (2.74)	P = 0.027
Ground			
~25 m	2	30.25 (12.33)	t = −1.22
~100 m	6	37.50 (5.72)	P = 0.270

Table 4. Comparison of faunal similarity and edge effect for each stratum.

	Morisita-Horn		
Trap Location	N	Mean (SD)	*t* Test
Elevated			
similar distance from edge	16	.710 (.092)	
			t = .110 P = .913
dissimilar distance from edge	12	.706 (.090)	
Ground			
similar distance from edge	16	.587 (.085)	
			t = .122 P = .904
dissimilar distance from edge	12	.583 (.087)	

ACKNOWLEDGEMENTS

I would like to thank Michael Ulyshen and James Hanula for sharing their unpublished results, Joe Keiper for his review of a draft and assistance with the statistical analysis, James Bissell and Keith Vouk for access to the study site, Ilari Sääksjärvi, Mark Shaw, and an anonymous reviewer for their helpful evaluations, and Hans Clebsch for identification of the Diapriidae.

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